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ABSTRACT

In the 20 years since the publication of "Frames of Mind" by Howard Gardner, two major developments have altered the prospects for making a connection between neuropsychology and theories of how people differ. The first of these events was that electrical or magnetic recording make it possible to "see" inside the brain as people think. Results from imaging studies provide support for Gardner's distinction among domains in terms of the separable anatomical networks they activate. The second major event has been the sequencing of the entire human genome. Results from recent studies suggest that it is possible to examine individual efficiency in specific neural networks by combining the methods of brain imaging with modern genetic studies. Attention is not one of Gardner's multiple intelligences, but it is an area in which progress is being made in integrating individual differences with general properties of the mind. Research on attention may have important applications for education, and it may be that the training of attention will become an important part of early childhood education. (Contains 28 references.) (SLD)

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NEURAL SYSTEMS AND INDIVIDUAL DIFFERENCES: A COMMENTARY ON FRAMES OF MIND: THE THEORY OF MULTIPLE INTELLGENCES

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One of the major contributions of Howard Gardner's book, Frames of Mind containing the theory of multiple intelligences was an important link between two major approaches to psychology, which were then and for the most part still are, quite separate. First, was an approach to the common mental processes and behavior of human beings and second, was the psychometrics of individual differences implicit in the term intelligences. Gardner's effort to embed the measurement of individual difference in intelligence within a theory based on neuropsychology was of note for psychology independent from its application to education and other domains. This aspect of Frames of Mind has been under appreciated, perhaps because the two approaches continued along their separate way in the years following the book. However, it may be time to salute Gardner by renewing his effort to forge a deeper connection between cognitive psychology and psychometrics. Current studies in cognitive neuroscience may have potential for accomplishing this goal and could also provide some new approaches to research on education.

NEUROIMAGING

In the twenty years since the book, two major developments have greatly altered the prospects for making a connection between neuropsychology, as an effort to relate general principles of psychology to brain systems, with theories of how people differ. The first of these events was that for the first time, we could glimpse inside the human brain as people think (Posner & Raichle, 1994). When combined with electrical or magnetic recording from outside the skull one can see in real time the circuits involved in computing aspects of the task. Although some parts of this technology had been around for a long time, only in the fifteen years did it become

clear that a new era had arrived in our ability to create local images of human brain activity through changes in cerebral blood flow.

Being able to see things has always had a dramatic impact in science. The microscope allowed people to see things too small to be observed by our senses. At the beginning of the 20th century Santiago Ramon y Cajal (1937) was able for the first time to observe individual nerve cells. Our current ability to see into the human brain depends on the operation of these nerve cells. When neurons are active, they change their own local blood supply. This makes it possible to trace areas of the brain that are active during cognitive processes by measuring local changes in aspects of the brains blood supply.

Gardner outlined several forms of intelligence: linguistic, musical, logical-mathematical, spatial, bodily kinesthetic and inter and intra personal. Neuroimaging studies have used activation tasks that can be seen as involving all of these forms of intelligence. For example, presentation of visual and auditory words activate a largely left sided set of areas of the anterior and posterior cortex and the cerebellum. Simple arithmetical tasks that involve processing the quantity of a visual digit activate left and right occipital and parietal areas. There is also some information on musical (Zatorre, 1999) and spatial tasks (Corbetta & Shulman, 2002) and on an understanding of the minds of others (Frith & Frith, 2001) and of oneself (Gusnard, Abdudak, Shulman & Raichle, 2001). While, these networks sometimes overlap, for example, the networks for music have nodes rather close to those used for simple arithmetic and spatial attention, it seems likely that they have quite distinct anatomies. These results provide support for Gardner's distinction among domains in terms of the separable anatomical networks they activate.

It is also important to note that these networks have not proven to be as separate as though they were in different brains. Indeed each node in these networks communicates with other nodes of the network and with other networks. For example, one can use language to instruct oneself to move attention to a new location and when tasks require both, language and spatial attention both networks are activated. Exact calculation of numerical quantity can

bring in language networks. If a visual digit is spelled out making a word, it will activate left occipital areas that are also activated by non-numerical words. These are all important examples of how real world actions may draw upon multiple neural systems and thus related to multiple forms of intelligence.

While it is possible to use imaging data to argue for separate networks underlying each of the domains outlined by Gardner (1983; 1999), it would be impossible to argue from imaging data that these are the only separable domains. Indeed it is more likely that different tasks clearly within one domain can still be distinguished by their functional anatomy. Gardner does not claim that his intelligences exhaust the list, more importantly he does not make the distinction among intelligences on anatomy alone. This is only one of the eight criteria that he advocates using in order to claim a separate intelligence. Many of these criteria require individual measurement to be accomplished in a way that can be used to examine the genetics and development of the network.

HUMAN GENOME

The second major event at the end of the 20th century was sequencing the entire human genome (Ventner, et al, 2001). Now it was possible not only to study the functional anatomy of brain networks, but also to examine how genetic differences might lead to individual variations in the potential to use these networks in order to acquire and perform skills. However, the route from genetic endowment to performance is neither simple nor separate from an understanding of the brain networks themselves.

Gardner assumed that higher ability in any domain (e.g. linguistic intelligence) would mean more efficient use of whatever the underlying neural mechanisms turned out to be. This assumption is quite reasonable at an abstract level, but now that one can actually image networks underlying verbal or mathematical skills, we need to know what in the networks activity corresponds to the idea of greater efficiency of use. One possibility is that more efficient use means that, for any given level of task performance, there will be reduced activation of nodes within the network. This idea has support from developmental studies that have been

interpreted as showing that children activate a large neural network that contains within it the areas that would be activated by a skilled adult performing the same task (Casey, Trainor, Orendi, Schubert, et al, 1997). It also is supported by the finding that priming or repeating activation of the same network leads to a reduction in its strength of activation (Wiggs & Martin, 1998), or even a complete elimination of activation in one network with substitution of another network (Raichle, Fiez, Videen, McCleod, et al, 1994). However, there is exception to reduced activation, cases in which learning or development actually leads to an expansion of the area of neural activity required (Karni, Meyer, Rey-Hipolito, Jezzard, et al, 1998; Schlagger, Brown, Lugar, Visscher, et al, 2002). It appears now that only more empirical facts will allow us to develop and test specific ideas of how efficiency of a network is related to its activation.

In the domain of attention we have begun to develop methods for examining the efficiency of particular neuro-networks in individuals to study how genes and specific experience change them in the course of human development.

The attention network task (ANT) (Fan, McCandliss, Sommer, Raz & Posner, 2002) was developed to assay the efficiency of three attentional networks. It requires only that the person press one key if a central arrow points leftward and another key when it points rightward. Flanking arrows may either have the same direction as the target (congruent) or the opposite direction (incongruent). The difference in efficiency between congruent and incongruent conditions measures the executive function of resolving conflict. This task activates a frontal network including the anterior cingulate. Cues introduced before the target warn the person and can orient them to the location of the target. A study of 40 adults found relatively high immediate retest reliability for the scores of each attentional network provided by the ANT test (Fan et al, 2002). An ANT test specifically developed for children uses colorful fish to replace the arrows and children are invited to feed the fish (Rueda, Fan, McCandliss, Halparin, Gruber & Posner, 2002). This version of the ANT was used to study children between 6 and 10 years of age to examine changes in attentional networks over this period and from this period to adulthood. Independence between the network

scores for the child version of the ANT was shown both by the lack of correlation between the three scores and the finding of no interactions between cue conditions and target flanker condition.

There are also clear differences in development between the networks. For example the executive network scores showed a marked decrease between ages 4 and 7, but following age 7 there is remarkably little difference in RT or errors up to and including adults. This result is surprising given the general expectation that the executive network would improve until adulthood, as children are able to solve more difficult problems. However, our results fit rather well with the previous literature using the flanker task. A previous developmental study of the flanker task (Ridderinkhof, vand er Molen, Band & Bayshore, 1997) showed improvement in conflict from age five to ten and then little difference between this age and adults. Alerting showed continued development between ten year olds and adults, while orienting seemed to reach adult levels even before age six.

A series of pharmacological studies with alert monkeys have related the attentional networks discussed above with specific chemical neuromodulators (Davidson & Marrocco, 2000; Marrocco & Davidson, 1998). Alerting is thought to involve the cortical distribution of the brain's norepinepherine (NE) system arising from neurons with cell bodies in the locus coeruleus of the midbrain. Drugs like clonidine and guanfacine act to block NE, and reduce or eliminate the normal effect of warning signals on reaction time, but have no influence on orienting to the target location. Cholinergic systems arising in the basal forebrain play a critical role in orienting. Lesions of the basal forebrain in monkeys interfere with orienting attention (Voytko, Olton, Richardson, Gorman, et al, 1994). However, it does not appear that the site of this effect is in the basal forebrain. Instead it appears to involve the superior parietal lobe. Injections of scopolamine directly into the lateral intraparietal area of monkeys, a brain area containing cells that are influenced by cues about spatial location, have been shown to have a large effect on the ability to shift attention to a target. Cholinergic drugs do not affect the ability of a warning signal to improve performance and thus there is a double dissociation that relates NE to the alerting network and Ach (acetylcholine) to the orienting

network. The executive network involves the anterior cingulate and lateral frontal cortex modulated by the dopamine (DA) system.

A twin study of attention suggested that the executive attention network had high heritability (Fan, Wu, foxxella & Posner, 2001). For this reason genes were examined related to the dompamine system (Fossella, Sommer, Fan, Wu, Swanson, et al, 2002). Four genes in this system were found to be related to the executive network. When genes with relatively good executive performance in the ANT were compared with those which gave relatively bad performance in an fMRI study, the major difference between the subjects was in the anterior cingulate, a part of the executive network (Fan, Fossella , Sommer & Posner, 2003).

These results suggest that it is possible to examine individual efficiency in specific neural networks by combining the methods of brain imaging with modern genetic studies.

ATTENTION AND MULTIPLE INTELLIGENCES

Attention is not one of Gardner's intelligences. Given the kinds of data outlined above why not? Attention would seem to fit all of Gardner's criteria with the possible exception of having its own symbol system. Attention seems to use the symbolic representations of whatever domain, for example, language, space or music is attended. Moreover, despite the interest in meditation and hypnotism we just do not generally consider champions in ability to attend as special in our society the way we do with verbal, music or social skills.

I am not lobbying to have attention added to Gardner's systems. However, in so far as one values the goal of integrating individual differences with general properties of the mind, attention is an area where progress is being made in doing this through observing activation of specific neural networks in imaging studies and then studying their development under genetic and experiential control. Although there is much remaining to do within the field of attention, I think this approach might do well for all of the topics of multiple intelligences and indeed all of the areas of cognitive psychology. In nearly every area imagers have been able to

discover networks of neural areas related to the skill. Although there are not always available clues as to what are the likely candidates, genes can be obtained in a number of areas such as reading, number processing and music that have specific deficits providing candidate alleles for genetic studies. It seems likely that the study of the development of specific neural networks underlying all the domains of Gardner's book and others as well will be the topic of study in cognitive neuroscience over the next few years. This approach might succeed in producing the integration Gardner suggested twenty years ago, but which still remains to be achieved in psychological laboratories.

Research on attention may also have important applications for education. Both cognitive and behavioral theories of learning have shown that it is specific to individual domains (Duda & Shortliffe, 1983; Thorndike & Woodworth, 1901) and this view is also implicit in the multiple intelligences approach. If attention can be taught it might be an exception to domain specific learning, since attention is important for explicit learning in most or all domains. Research has provided us with specific developing networks underlying attention. My current research together with Mary K. Rothbart at the University of Oregon is directed toward determining whether we can make improvements in attention by training and to see if they aid in the acquisition of domain specific areas such as literacy and numeracy (OECD, 2002; Posner & Rothbart, 2002). If this or related work shows it is possible to improve attention with training, the training of attention could become an important part of early childhood education.

References

Cajal, S. R.Y. (1937). *Recollection of my life.* Philadelphia: American Philosophical Society.

Casey, B. J., Trainor, R. J., Orendi, J. L., Schubert, A. B., Nystrom, L. E., Giedd, J. N., Castellanos, F. X., Haxby, J. V., Noll, D. C., Cohen, J. D., Forman, S. D., Dahl, R. E., & Rapoport, J. L. (1997). A developmental functional MRI study of prefrontal activation during performance of a go-no-go task. *Journal of Cognitive Neuroscience* 9:835-847.

Corbetta, M. & Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Neuroscience Reviews*, **3**:201-215.

Davidson, M.C. & Marrocco, R.T. (2000). Local infusion of scopolamine into intraparietal cortex slows covert orienting in rhesus monkeys. *Journal of Neurophysiology*, **83**:14 36-49.

Duda, R.O. & Shortliffe, E.H. (1983) Expert systems research *Science* **220**. 261-268

Fan, J., McCandliss, B.D., Sommer, T., Raz, M. & Posner, M.I. (2002). Testing the Efficiency and Independence of Attentional Networks. *Journal of Cognitive Neuroscience*, **3**:14 340-347.

Fan, J, Wu, Y., Fossella, J. & Posner, M.I. (2001). Assessing the heritability of attentional networks. *BioMed Central Neuroscience*, **2**:14.

Fan, J, Fossella, J. & Posner, M.I. (2003). Effect of genotype on executive attention performance and brain activation. *Cognitive Neuroscience* , **14**:340-347.

Fossella, J., Sommer T., Fan,J., Wu ,Y., Swanson, J.M., Pfaff, D.W. & Posner, M.I. (2002). Assessing the molecular genetics of attention networks *BioMed Central Neuroscience*, **3**:14.

Frith U., & Frith C. (2001). The biological basis of social interaction. *Current Directions in Psychological Science*, **10**:151-155.

Gardner, H. (1938). *Frames of Mind: The Theory of Multiple Intelligences.* New York:Basic Books.

Gardner, H. (1999). *Intelligence Reframed.* New York:Basic Books.

Gusnard, D.A., Akbudak,E., Shulman, G.L. & Raichle, M.E. (2001). Medial prefrontal cortex and self-referential mental activity:

Relation to a default mode of brain function. *Proceedings of National Academy of Sciences, USA*, 4259-64.

Karni, A., Meyer, G., Rey-Hipolito,C., Jezzard, P., Adams, M.M., Turner, R., & Ungerledier, L.G. (1998). The acquisition of skilled motor performance: Fast and slow experience driven changes in primary motor cortex. *Proceedings of National Academy of Sciences, USA*, **95**:861-868.

Marrocco, R.T. & Davidson, M.C. Neurochemistry of attention. In Parasuraman, R., (ed.), *The Attention Brain.* Cambridge, MA: MIT Press, 35-50.

OECD (2002) Understanding the brain: toward a new learning science. Paris: OECD

Posner, M.I. & Raichle, M.E. (1994). *Images of Mind.* Scientific American Books.

Posner, M.I. & Rothbart, M.I.(2002) Il cervello e líattenzione nel contesto scolastico
(The Human Brain and Attention to School Subjects) in Elisa Frauenfelder & Flavia Santoianni (eds) Le Science Bioeducative Naples:Liguori, Srl 5-20

Raichle, M.E., Fiez, J.A., Videen, T.O., McCleod, A.M.K., Pardo, J.V., Fox,P.T., & Petersen, S.E. (1994). Practice-related changes in the human brain: Functional anatomy during non-motor learning. *Cerebral Cortex*, **4**:8-26.

Ridderinkhof, K.R., van der Molen, M.W., Band, P.H. & Bashore, T.R. (1997). Sources of interference from irrelevant information: A developmental study. *Journal of Experimental Child Psychology*, **65**:315-341.

Rueda, M.R., Fan,J., McCandliss, B.D., Halparin, J., Gruber, D, & Posner, M. I. (2001). Assaying the development of attentional networks in six to ten year old children. *Society for Cognitive Neuroscience Abstract*, p 22.

Schlagger, B.L., Brown, T.T., Lugar, H.M., Visscher, K.M., Miezin, F.M., & Petersen, S.E. (2002). Functional neuroanatomical differences between adults and school-age children in processing of single words. *Science,* **296**:1476-1479.

Thorndike, E.L. & Woodworth, (1901) The influence of one mental function upon the efficiency of other functions. *Psychological Review,* **8**, 247-261, 384-395, 553-564.

Ventner, et al, (2001). The sequence of the human genome. *Science* **291**:1304-1350.

Voytko, M. L., Olton, D. S., Richardson, R. T., Gorman, L. K., Tobin, J. R. & Price, D. L. (1994). Basal forebrain lesions in monkeys disrupt attention but not learning and memory. *Journal of Neuroscience,* **14(1)**:167-186.

Wiggs, C.L. & Martin, A. (1998). Properties and mechanisms of perceptual priming. *Current opinion in Neurobiology,* **8**:227-233.

Zatorre, R.J. (1999). Brain imaging studies of musical perception and musical imagery. *Journal of New Music Research,* **28**(3): 229-236.

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